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CATEGORY II
FB-111A RELIABILITY AND MAINTAINABILITY EVALUATION THROUGH NOVEMBER 1970

JAN M. HOWELL
Reliability and Maintainability Engineer

INTERIM TECHNICAL REPORT No. 70-36

AIR FORCE FLIGHT TEST CENTER
EDWARDS AIR FORCE BASE, CALIFORNIA
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE

FTC-TR-70-36

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FOREWORD

This is the first of a series of interim reports presenting reliability and maintainability measurements and analysis from the FB-111A Category II test program. Each report will contain a complete analysis of the test data to that point. The FB-111A Category II flight test program was initiated by Air Force Flight Test Center Project Directive 67-1, 13 July 1966.

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ABSTPACT

This report presents a reliability and maintainability analysis resulting from FB-111A Category II testing at Edwards AFB from 31 August 1968 through 15 November 1970. Assigned aircraft have flown 311 hours during 141 missions (including aborts). The FB-111A has demonstrated a mean time between major subsystem failures of 5.0 flying hours. During the last six months of testing (15 May through 15 November 1970), the FB-111A fleet assigned to Category II testing required 111.8 maintenance manhours per flying hour. The large maintenance-manhour-per-flying hour statistic was attributed to low flying hours and low aircraft reliability. The low amount of flying hours was due to technical order compliance, coldproof testing, and temporary groundings along with low reliability (which reduced aircraft availability).

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LIST OF ABBREVIATIONS AND SYMBOLS

Item	Definition	Units
CMRS	countermeasures receiving set	- - -
IFF	identification, friend or foe	- - -
ILS	instrument landing system	- - -
IRU	inertial reference unit	- - -
JTF	joint test force	- - -
LCL	lower confidence limit	- - -
MMH/FH	maintenance manhours per flying hour	- - -
MTBA	mean time between aborts	hr
MTBD	mean time between discrepancies	hr
MTBF	mean time between failures	hr
N	the sample size; the number of data points	- - -
N_a	the number of missions on which aborts were recorded against the subsystem	- - -
N_d	the number of missions on which degraded operation was recorded against the subsystem	- - -
N_f	the number of missions on which failures were recorded against the subsystem	- - -
N_s	the number of missions on which successes were recorded against the subsystem	- - -
ODS	optical display sight	- - -
p	lower confidence limit probability	- - -
P_{na}	probability of no aborts	- - -
P_{nd}	probability of no discrepancies	- - -
P_{nf}	probability of no failures	- - -
R	number of failures accumulated	- - -
RHAWS	radar homing and warning set	- - -
R/T	receiver/transmitter	- - -
SEDS	Systems Effectiveness Data System	- - -
t	time	- - -
T	total system operating (flying) time	- - -
tacan	tactical air navigation	- - -
TFR	terrain following radar	- - -
WUC	work unit code	- - -
α	acceptable risk or probability of error	- - -
χ^2	chi-square distribution	- - -
$1-\alpha$	confidence level	- - -

I. INTRODUCTION

This report presents the results of the FB-111A Reliability and Maintainability Evaluation obtained during Category II testing. The data used in this evaluation have been accumulated from the four aircraft assigned to the F-111 Joint Test Force (JTF) (FB-111A production numbers 1, 3, 6, and 27). Table I-1 contains a summary of missions during Category II testing. The limited amount of flying time was due to the time required for technical order compliance, coldproof testing and temporary groundings along with low reliability (which reduced availability.

These aircraft have not been tested in an operational environment, but peculiarities of the test environment have been eliminated from the data or accounted for whenever possible. Data collection methods are described in appendix I.

Table I-1

FB111A CATEGORY II
MISSION SUMMARY

MONTH	ACFT S/N	CODE	CAT II MISSIONS	FLIGHT TIME *	SUPERSONIC TIME *	WING SWEEPS	LANDINGS	DISCREPANCIES
AUG 1968	67152	I	1	3.5	0.1	8	1	2
	TOTAL		1	3.5	0.1	8	1	2
SEP 1968	67159	L	4	9.5	0.3	17	12	14
	TOTAL		4	9.5	0.3	17	12	14
OCT 1968	67159	L	8	25.9	0.4	49	18	20
	TOTAL		8	25.9	0.4	49	18	20
NOV 1968	67159	L	11	30.9	0.1	59	15	10
	TOTAL		11	30.9	0.1	59	15	10
DEC 1968	67159	L	23	59.0	0.4	150	43	17
	TOTAL		23	59.0	0.4	150	43	17
JAN 1969	67159	L	6	21.7	0.2	57	14	6
	TOTAL		6	21.7	0.2	57	14	6
AUG 1969	67161	M	1	3.5	0.	12	1	3
	TOTAL		1	3.5	0.	12	1	3

*hours

Table I-1 (Concluded)

MONTH	ACFT S/N	CODE	CAT II MISSIONS	FLIGHT TIME *	SUPERSONIC TIME *	WING SWEEPS	LANDINGS	DISCREPANCIES
SEP 1969	67161	M	7	14.5	0.8	51	13	19
	TOTAL		7	14.5	0.8	51	13	19
OCT 1969	67161	M	8	8.2	0.3	45	8	14
	TOTAL		8	8.2	0.3	45	8	14
NOV 1969	67161	M	2	1.4	0.1	4	2	3
	TOTAL		2	1.4	0.1	4	2	3
DEC 1969	67161	M	23	32.3	1.6	143	21	27
	67192	N	1	4.4	0.	2	1	2
	TOTAL		24	36.7	1.6	145	22	29
MAR 1970	67161	M	2	4.2	0.	4	7	3
	67192	N	1	4.0	0.	4	1	2
	TOTAL		3	8.2	0.	8	8	5
APR 1970	67159	L	2	4.3	0.	5	3	5
	TOTAL		2	4.3	0.	5	3	5
MAY 1970	67161	M	2	4.4	0.	7	2	8
	TOTAL		2	4.4	0.	7	2	8
JUN 1970	67161	M	7	6.6	0.8	31	11	10
	TOTAL		7	6.6	0.8	31	11	10
AUG 1970	67161	M	13	14.1	0.2	53	17	26
	TOTAL		13	14.1	0.2	53	17	26
SEP 1970	67159	L	1	3.2	0.	7	1	3
	67161	M	6	16.1	0.	24	5	8
	TOTAL		7	19.3	0.	31	6	11
OCT 1970	67159	L	5	15.5	0.	94	6	6
	67161	M	11	20.2	0.7	124	23	19
	68255	T	1	3.7	0.	2	1	4
	TOTAL		17	39.4	0.7	220	30	29
NOV 1970	67161	M	3	6.1	0.4	23	4	4
	68255	T	1	2.7	0.	2	1	3
	TOTAL		4	8.8	0.4	25	5	7
				CUMULATIVE TOTALS AUG 1968 - NOV 1970				
	67159	L	58	164.6	1.4	437	110	83
	67161	M	95	131.7	5.0	521	114	144
	67192	N	2	8.4	0.	6	2	4
	68255	T	2	6.4	0.	4	2	7
	GRAND TOTAL		147	311.1	6.5	968	228	238

*hours

II. RELIABILITY ANALYSIS OF AIRCREW-DISCOVERED MALFUNCTIONS

2.1 Introduction:

The data presented are intended to provide numerical analysis of subsystem reliability. Reliability data were obtained by using failure information from the debriefing file; therefore, the study was based on flight crew-discovered malfunctions. As subsystem malfunctions occurred they were classified as degraded operations or failures. A degraded operation existed when the performance of a subsystem was below normal operating specifications but was still usable. When a subsystem was rendered inoperative or unusable, the malfunction was classified as a subsystem failure. There were two types of subsystem failures, no-abort and abort. No-abort failures occurred when the subsystem failed, but was not mission essential and did not cause a mission to be aborted. When a subsystem was mission essential and had a failure that caused the mission to be terminated before completion, the malfunction was classified as an abort failure.

2.2 Subsystem Mission Malfunction Report:

The Subsystem Mission Malfunction Report (table II-1) shows the flight time and the number of malfunctions that occurred on the different aircraft subsystems. Also shown is the number of missions on which each subsystem had no malfunctions. The operating time of each subsystem was taken to be the flight time on those missions when the subsystem was used. No time was credited for those missions when the subsystem was not used. Likewise, no time was credited for ground operating time or maintenance checkout time.

2.3 Subsystem Mission Reliability Report:

The Subsystem Mission Reliability Report (table II-2) shows calculated values of the mean times between malfunctions according to type (part 1) and the probabilities of not having a malfunction of each type (part 2). The large differences between some of the measured mean times and probabilities and the associated lower confidence limits (LCL's) resulted from the low utilization rates of some subsystems. Calculation procedures are presented in appendix II. Based on this procedure, the FB-111A demonstrated a mean time between subsystem failures of 5.0 hours.

Table II-1

	SUCCESS	DISCREP	FAIL	ABORT	TIME
AIRFRAME	134	2	5	0	311.14
LANDING GEAR	135	4	1	0	311.14
FLIGHT CONTROL	131	4	6	2	306.81
ESCAPE CAPSULE	137	0	0	0	303.64
ENGINES	125	14	1	3	311.14
AIR COND, PRESS	128	7	1	0	303.14
ELECTRICAL PWR	139	1	0	0	311.14
LIGHTNING SYSTM	134	6	0	0	311.14
HYD,PNEUM PWR	140	0	0	0	311.14
FUEL	133	6	1	0	307.97
AIR REFUELING	8	3	0	0	36.80
OXYGEN SYSTEM	138	1	0	0	307.39
MISC UTILITIES	139	0	0	0	309.14
INSTRUMENTS	113	23	4	0	308.81
AUTO PILOT	110	10	3	3	291.60
AIR DATA	137	0	0	0	303.91
HF COMM	43	1	2	0	123.95
UHF COMM	115	20	2	0	304.98
INTERPHONE	137	1	1	0	306.37
IFF/SIF	129	2	3	0	299.98
MISC COMM	138	0	0	0	306.97
TACAN	130	4	1	0	306.64
ILAS	29	4	1	0	81.37
UHF/ADF	7	0	0	0	18.75
RNDZ BEACON	8	0	0	0	27.55
INERIAL NAV	118	10	7	0	300.13
ATTACK RADAR	116	16	3	1	306.39
RADAR ALTIMETER	131	3	0	0	304.73
TFR	13	0	2	0	36.90
DOPPLER	95	4	1	0	221.25
ASTRO-TRACKER	23	0	2	0	41.05
DISPLAY SYSTEM	107	2	0	0	248.67
ODS	108	1	0	0	245.64
BOMB TIMER	6	0	0	0	18.84
COMPUTER COMPLX	102	3	3	0	261.15
PYLONS	29	0	0	0	48.68
WEAPONS BAY	23	5	0	0	46.36
WEAPONS CONTROL	27	1	0	1	43.62
WEAPONS RACKS	26	0	0	0	40.71
TRK BRKR SYSTEM	1	0	0	0	2.75
CMRS	1	0	0	0	2.75
RHAWS	2	0	1	0	9.75
INSTRUMENTATION	98	3	4	4	228.36

Table II-2
Part 1

	MEAN TIME BETWEEN DISCREPANCY (hours)		MEAN TIME BETWEEN FAILURE (hours)		MEAN TIME BETWEEN ABORT (hours)	
	MEASURED	90 PERCENT LOWER CONFIDENCE LIMIT	MEASURED	90 PERCENT LOWER CONFIDENCE LIMIT	MEASURED	90 PERCENT LOWER CONFIDENCE LIMIT
AIRFRAME	44.4	26.4	62.2	33.5	NO ABORT	135.1
LANDING GEAR	62.2	33.5	311.1	80.0	NO ABORT	135.1
FLIGHT CONTROL	25.6	17.3	38.4	23.6	153.4	57.6
ESCAPE CAPSULE	NO DISC	131.9	NO FAIL	131.9	NO ABORT	131.9
ENGINES	17.3	12.6	77.8	38.9	103.7	46.6
AIR COND, PRESS	37.9	23.3	303.1	77.9	NO ABORT	131.7
ELECTRICAL PWR	311.1	80.0	NO FAIL	135.1	NO ABORT	135.1
LIGHTNING SYSTM	51.9	29.5	NO FAIL	135.1	NO ABORT	135.1
HYD,PNEUM PWR	NO DISC	135.1	NO FAIL	135.1	NO ABORT	135.1
FUEL	44.0	26.2	308.0	79.2	NO ABORT	133.8
AIR REFUELING	12.3	5.5	NO FAIL	16.0	NO ABORT	16.0
OXYGEN SYSTEM	307.9	79.2	NO FAIL	133.7	NO ABORT	123.7
MISC UTILITIES	NO DISC	134.3	NO FAIL	134.3	NO ABORT	134.3
INSTRUMENTS	11.4	8.8	77.2	38.6	NO ABORT	134.1
AUTO PILOT	18.2	13.0	48.6	27.7	97.2	43.6
AIR DATA	NO DISC	131.9	NO FAIL	131.9	NO ABORT	131.9
HF COMM	41.3	18.6	69.0	23.3	NO ABORT	53.8
UHF COMM	13.9	10.4	152.5	57.3	NO ABORT	132.5
INTERPHONE	153.5	57.7	307.0	78.9	NO ABORT	133.3
IFF/SIF	60.0	32.3	100.0	44.9	NO ABORT	130.3
MISC COMM	NO DISC	133.3	NO FAIL	133.3	NO ABORT	133.3
TACAN	61.3	33.1	306.6	73.8	NO ABORT	133.2
ILAS	16.3	9.3	81.4	20.9	NO ABORT	35.3
UHF/ADF	NO DISC	8.1	NO FAIL	8.1	NO ABORT	8.1
RNDZ BEACON	NO DISC	12.0	NO FAIL	12.0	NO ABORT	12.0
INERIAL NAV	17.7	12.7	42.9	25.5	NO ABORT	130.3
ATTACK RADAR	15.3	11.3	76.6	38.3	306.4	78.9
RADAR ALTIMETER	101.6	4 .6	NO FAIL	132.3	NO ABORT	132.3
TFR	18.4	6.9	18.4	6.9	NO ABORT	16.0
DOPPLER	44.2	23.9	221.2	56.9	NO ABORT	96.1
ASTRO-TRACKER	20.5	7.7	20.5	7.7	NO ABORT	17.9
DISPLAY SYSTEM	124.3	46.7	NO FAIL	108.0	NO ABORT	108.0
ODS	245.6	63.2	NO FAIL	106.7	NO ABORT	106.7
BOMB TIMER	NO DISC	8.2	NO FAIL	8.2	NO ABORT	8.2
COMPUTER COMPLX	43.5	24.8	87.0	39.1	NO ABORT	113.4
PYLONS	NO DISC	21.1	NO FAIL	21.1	NO ABORT	21.1
WEAPONS BAY	9.3	5.0	NO FAIL	20.1	NO ABORT	20.1
WEAPONS CONTROL	21.8	8.2	43.6	11.2	43.6	11.2
WEAPONS RACKS	NO DISC	17.7	NO FAIL	17.7	NO ABORT	17.7
TRK BRKR SYSTEM	NO DISC	1.2	NO FAIL	1.2	NO ABORT	1.2
CMDS	NO DISC	1.2	NO FAIL	1.2	NO ABORT	1.2
RHAWS	9.7	2.5	9.7	2.5	NO ABORT	4.2
INSTRUMENTATION	20.4	13.8	28.5	17.6	57.1	28.6

Table II-2
Part 2

	PROBABILITY OF NO DISCREPANCY		PROBABILITY OF NO FAILURE		PROBABILITY OF NO ABORT	
	MEASURED	90 PERCENT LOWER CONFIDENCE LIMIT	MEASURED	90 PERCENT LOWER CONFIDENCE LIMIT	MEASURED	90 PERCENT LOWER CONFIDENCE LIMIT
AIRFRAME	0.95	0.92	0.96	0.94	1.00	0.99
LANDING GEAR	0.96	0.94	0.99	0.98	1.00	0.99
FLIGHT CONTROL	0.92	0.88	0.94	0.91	0.99	0.97
ESCAPE CAPSULE	1.00	0.99	1.00	0.99	1.00	0.99
ENGINES	0.87	0.83	0.97	0.95	0.98	0.96
AIR COND, PRESS	0.94	0.91	0.99	0.98	1.00	0.99
ELECTRICAL PWR	0.99	0.98	1.00	0.99	1.00	0.99
LIGHTNING SYSTM	0.96	0.93	1.00	0.99	1.00	0.99
HYD,PNEUM PWR	1.00	0.99	1.00	0.99	1.00	0.99
FUEL	0.95	0.92	0.99	0.98	1.00	0.99
AIR REFUELING	0.73	0.49	1.00	0.81	1.00	0.81
OXYGEN SYSTEM	0.99	0.98	1.00	0.99	1.00	0.99
MISC UTILITIES	1.00	0.99	1.00	0.99	1.00	0.99
INSTRUMENTS	0.81	0.76	0.97	0.95	1.00	0.99
AUTO PILOT	0.87	0.83	0.95	0.92	0.98	0.95
AIR DATA	1.00	0.99	1.00	0.99	1.00	0.99
HF COMM	0.93	0.87	0.96	0.93	1.00	0.97
UHF COMM	0.84	0.80	0.99	0.97	1.00	0.99
INTERPHONE	0.99	0.97	0.99	0.98	1.00	0.99
IFF/SIF	0.96	0.94	0.98	0.95	1.00	0.99
MISC COMM	1.00	0.99	1.00	0.99	1.00	0.99
TACAN	0.96	0.94	0.99	0.98	1.00	0.99
ILAS	0.85	0.76	0.97	0.91	1.00	0.95
UHF/ADF	1.00	0.72	1.00	0.72	1.00	0.72
RNDZ BEACON	1.00	0.75	1.00	0.75	1.00	0.75
INERIAL NAV	0.87	0.83	0.95	0.92	1.00	0.99
ATTACK RADAR	0.85	0.81	0.97	0.95	0.99	0.98
RADAR ALTIMETER	0.98	0.95	1.00	0.99	1.00	0.99
TFR	0.87	0.68	0.87	0.68	1.00	0.86
DOPPLER	0.95	0.91	0.99	0.97	1.00	0.98
ASTRO-TRACKER	0.92	0.80	0.92	0.80	1.00	0.91
DISPLAY SYSTEM	0.98	0.96	1.00	0.99	1.00	0.99
ODS	0.99	0.97	1.00	0.99	1.00	0.99
BOMB TIMER	1.00	0.68	1.00	0.68	1.00	0.68
COMPUTER COMPLX	0.94	0.91	0.97	0.94	1.00	0.99
PYLONS	1.00	0.92	1.00	0.92	1.00	0.92
WEAPONS BAY	0.82	0.69	1.00	0.92	1.00	0.92
WEAPONS CONTROL	0.93	0.83	0.97	0.87	0.97	0.87
WEAPONS RACKS	1.00	0.92	1.00	0.92	1.00	0.92
TRK BRKR SYSTEM	1.00	0.10	1.00	0.10	1.00	0.10
CMPS	1.00	0.10	1.00	0.10	1.00	0.10
RHAWS	0.67	0.20	0.67	0.20	1.00	0.47
INSTRUMENTATION	0.89	0.84	0.92	0.88	0.96	0.93

III. HARDWARE RELIABILITY ANALYSIS

3.1 Introduction:

The purpose of this section is to analyze all failures (both aircrew- and ground crew-discovered), calculate hardware mean time between failures (MTBF's), and to contrast the MTBF's with the contractor's apportioned values, when available. Appendix III discusses failure definitions and method of MTBF calculation.

3.2 Measured MTBF's:

Under the FB-111 contract the contractor was not required to, and has not, made available reliability apportionments for the various subsystems. These figures are, however, available for government furnished avionic equipment subsystems and for the MARK II avionics systems. For this reason it is not possible to compare MTBF measurements from Category II test with predicted MTBF's for all subsystems.

Table III-2 presents the measured MTBF's for those subsystems for which no MTBF values were apportioned. Table III-2 presents the measured MTBF's and contrasts these with apportioned MTBF's (references 1 and 2) for those systems where such apportioned MTBF's were available.

3.3 Component Reliability:

Although many of the failures discussed in tables III-1 and III-2 and in appendix V are seemingly random, it is possible to identify three specific components which have an excessive failure rate. These three components are the inertial reference unit, the general purpose computer and the converter.

Complete and accurate analysis requires that the aircraft under investigation be continuously assigned to Category II test so all failures and all operating time can be considered. The only aircraft which so far satisfies this requirement is FB-111A No. 3, and for this reason component reliability analysis was limited to this aircraft. Tables III-3, III-4 and III-5 present the life history of these three high failure items used in FB-111A No. 3.

Table III-1

MEASURED MTBF'S

(for which there were no allocated values)

Subsystem	Measured MTBF (flying hours)	Comment
Airframe	7.4	Worn seals and torn panels continue to present problems.
Landing gear	8.8	Seven tire changes and three tail hook panels lost in flight caused low MTBF.
Flight controls	6.5	Numerous hose, actuator, seal and movable surface failures caused the lowest reliability of any subsystem.
Escape capsule	32.3	Only minor problems such as counterpoise failures and oxygen leaks encountered with this subsystem.
Engine	10.8	Mainly failure of different type valves.
Air conditioning and pressurization	24.2	Duct cracks and valve failures.
Electrical power	48.5	Two failures of the external power monitor were the only problems with this system.
Lighting	-	No failures.
Hydraulic and pneumatic power	-	No failures.
Fuel	19.4	Five random failures.
Miscellaneous utilities	48.5	Two broken fire detection element cables.
Instruments	13.9	Two vertical speed indicator failures and two clock failures.
Autopilot	19.4	One gyro and four flight control computers accounted for all failures on this subsystem.
Weapons delivery	3.3	Three instances of door and panel damage and one inoperative door actuator.
Electronic Countermeasures	-	No flying hours.
Personnel Equipment	-	No failures.
Explosive Devices	-	No failures.

Table III-2

COMPARISON OF MEASURED AND APPORTIONED MTBF'S

Subsystem	Apportioned MTBF (hours)	Measured MTBF (flying hours)	Comments
HF communications	600	---	No failures.
UHF communications	273	32.3	Two R/T failures and one antenna failure.
Interphone	1000	---	No failures.
IFF	400	---	No failures.
Tacan	227	92.6	One R/T unit failure.
ILAS	300	22.8	One broken cable.
Radar altimeter	500	46.0	Two indicator failures.
Inertial navigation	620	22.8	Four reference unit failures.
Computer complex	600	28.8	Two computer failures and one converter failure.
Attack radar	137	13.3	Four synchronizer failures caused the majority of the problems with this subsystem.
TFR	197	12.1	One wiring problem and one transmitter failure.
Doppler radar	350	9.8	Two failures were caused by the electronics unit.
Display subsystem	2450	---	No failures.
Astrotracker	400	19.5	One electronic unit failure.
Optical display sight	450	---	Because of the unusability of this subsystem prior to incorporation of ECP2085, no attempt has been made to establish a reliability measurement.

Table III-3

INERTIAL REFERENCE UNIT FAILURE HISTORY

Date Installed	Date Removed	Serial Number	Part Number	Operating Time (hours)	Cause of removal
30 Aug 69	5 Sep 69	42	-31	13	INS-1 during preflight power transfer
5 Sep 69	4 Dec 69	35	-31	59	INS-1 (Bad Z velocity meter)
4 Dec 69	3 Jun 70	34	-31	86	Intermittent INS-1 and excessive ground speed (faulty Z velocity meter)
3 Jun 70	25 Aug 70	41	-31	45	Would not align and INS Heat Light ON
25 Aug 70	27 Aug 70	51	-41	2	IRU was not compatible with FB-111A No. 3.**
27 Aug 70	28 Sep 70	35	-31	196	INS-1 (faulty roll platform control amplifier)

CRITERIA:

Time period: 30 Aug 69 - 28 Sep 70
Aircraft: FB-111A No. 3
Flight time: 107.4 hours

Apportioned MTBF* - 620 hours
Measured MTBF - 80 operating hours/removal
22 flight hours/removal

*Reference: F-111 Avionics System Reliability Program Review, 5 Nov 69.

**This removal was not considered in the calculation of MTBF.

Table III-4

GENERAL NAVIGATION COMPUTER FAILURE HISTORY

Date Installed	Date Removed	Serial Number	Part Number	Operating Time (hours)	Cause of removal
30 Aug 69	17 Oct 69	85	6861600	216	Sequencing problem on bomb runs
17 Oct 69	7 Dec 69	72	6861600	23	Comp-1 (SDR parity error)
9 Dec 69	18 Dec 69	200	6861600	6	Would not come up (parity errors)
18 Dec 69	6 Jul 70	172	6861600	159	Would not come up (faulty power supply.

CRITERIA:

Time period: 30 Aug 69 - 6 Jul 70
Aircraft: FB-111A No. 3
Flight time: 77.1 hours
Apportioned MTBF* - 2,000 hours
Measured MTBF - 101 operating hours/removal
19 flight hours/removal

*Reference: F-111 Avionics System Reliability Program Review, 5 Nov 69.

Table III-5

CONVERTER SET FAILURE HISTORY

Date Installed	Date Removed	Serial Number	Part Number	Operating Time (hours)	Cause of removal
30 Aug 69	10 Dec 69	7	-41	194	Intermittent weapon release signal integrated circuit not seated (output driver board No. 73)
10 Dec 69	7 Jan 70	4	-41	4	Back to FB-1.**
7 Jan 70	27 May 70	45	-81	47	CS-2 indication (faulty synchro)
27 May 70	3 Jun 70	31	-81	40	CS-1 indication
3 Jun 70	4 Jun 70	16	-41	1	CS-3 indication (faulty discrete)
4 Jun 70	10 Jul 70	31	-81	19	Power supply in area III
10 Jul 70	12 Aug 70	9	-81	20	Failed six voltage level tests
12 Aug 70	7 Nov 70	31	-81	104	CS-3 overload indication

CRITERIA:

Time period: 30 Aug 69 - 7 Nov 70
Aircraft: FB-111A No. 3
Flight time: 130.4 hours

Apportioned MTBF* - 1,500 hours
Measured MTBF - 64 operating hours/removal
19 flight hours/removal

*Reference: F-111 Avionics System Reliability Program Review, 5 Nov 69.

**This removal was not considered in the calculation of MTBF.

IV. MAINTAINABILITY ANALYSIS

4.1 Introduction:

All maintenance data collected in the 258 Data System from 15 May through 15 November 1970 was the basis for the maintainability analysis. An analysis of the maintenance manhours per flying hour (MMH/FH) is presented in this section.

4.2 Maintenance Manhours per Flying Hour:

Table IV-1 presents the MMH/FH statistics for 16 May through 15 November 1970, the last six months in the reporting period. The MMH/FH expended at the line and shop levels and the percent of the total MMH/FH are shown for each WUC group. In addition, subtotals of support general and corrective MMH/FH and the total MMH/FH are shown.

4.3 Comparison of Allocated and Measured MMH/FH's:

The total MMH/FH (table IV-1) is considerably larger than the contractor guaranteed value of 40 MMH/FH.

The difference between a measured value of 40 MMH/FH for support general maintenance and the contractor allocation of 6.4 MMH/FH is primarily due to low aircraft utilization. Also, any comparison of support general MMH/FH's must consider the following usage restrictions from reference 3:

> "Military usage in excess of 2.8 MMH/FH shall not be chargeable to the contractor MMH/FH requirement. Military usage shall include all labor expended under WUC's 02, 05, 06, 07, 08, 09, that portion of code 01, Ground Handling and Service (ground handling only) and that portion of code 04, Special Inspections (Special Inspection for Modification, Test Flight, After Fire, Excessive "g", Hand Loading and Hot Start; Engine Trim, Weight and Balance, Compass Swing, Accident/Incident Investigation, Reclamation, Emergency Equipment Check, DD780 Inventory)."

For corrective maintenance, a value of 71 MMH/FH was measured and 17.4 MMH/FH was allocated. This difference was caused by low aircraft reliability.

Tables IV-2 and IV-3 contrast the contractor's allocated MMH/FH by subsystem with the measured values of this parameter along with comments on differences. These allocated values were abstracted from FZM-12-6118-3, Maintainability Engineering Analysis Data, reference 4.

Table IV-1

TITLE	WUC	LINE MMH/FH	LINE PERCENT OF TOTAL	SHOP MMH/FH	SHOP PERCENT OF TOTAL	TOTAL MMH/FH	TOTAL PERCENT OF TOTAL
GND HANDLING,SERVICE,FLY	1	7.4	6.6	0.4	0.3	7.7	6.9
AIRCRAFT CLEANING	2	0.3	0.3	0.	0.	0.3	0.3
LOOK PHASE OF INSPECTION	3	10.4	9.3	6.2	5.5	16.6	14.9
SPECIAL INSPECTIONS	4	8.3	7.4	0.	0.	8.3	7.4
A/C AND ENGINE STORAGE	5	0.	0.	0.	0.	0.	0.
GROUND SAFETY	6	0.1	0.1	0.	0.	0.1	0.1
PREPARATION A/C RECORDS	7	0.3	0.3	0.	0.	0.3	0.3
SPECIAL WPNS HANDLING	8	0.	0.	0.	0.	0.	0.
SHOP SUPPORT GENERAL	9	0.2	0.2	6.5	5.8	6.7	6.0
TOTALS FOR SUPPORT GENERAL		27.0	24.2	13.1	11.7	40.1	35.8

F8111A CATEGORY II
MAINTENANCE MANHOURS PER FLYING HOUR BY WORK UNIT CODE
FOR SUPPORT GENERAL MAINTENANCE ACTIONS

15 MAY 1970 THROUGH 15 NOVEMBER 1970

Table IV-1 (Continued)

TITLE	WUC	------LINE------ MMH/FH	PERC . OF TO	------SHOP------ MMH/FH	PERCENT CF TOTAL	------TOTAL----- MMH/FH	PERCENT OF TOTAL
AIRFRAME	11	5.0	4.5	1.0	0.9	6.0	5.3
LANDING GEAR	13	3.5	3.1	0.5	0.4	4.0	3.6
FLIGHT CONTROL	14	10.1	9.0	0.3	0.3	10.4	9.3
ESCAPE CAPSULE	16	3.5	3.1	0.	0.	3.5	3.1
TURBO JET POWER PLANT	23	2.6	2.3	1.1	1.0	3.7	3.3
AIR CONDITION,PRESSURE	41	4.7	4.2	0.	0.	4.7	4.2
ELECTRICAL POWER SUPPLY	42	0.2	0.2	0.	0.	0.2	0.2
LIGHTING SYSTEM	44	0.1	0.0	0.	0.	0.1	0.0
PNEUDRAULIC POWER SUPPLY	45	0.2	0.2	0.	0.	0.2	0.2

F8111A CATEGORY II
MAINTENANCE MANHOURS PER FLYING HOUR BY WORK UNIT CODE
FOR NONSUPPORT GENERAL MAINTENANCE ACTIONS(PAGE 1 OF 3)

15 MAY 1970 THROUGH 15 NOVEMBER 1970

Table IV -1 (Continued)

TITLE	WUC	------LINE------ MMH/FH	PERCENT OF TOTAL	------SHOP------ MMH/FH	PERCENT OF TOTAL	------TOTAL----- MMH/FH	PERCENT OF TOTAL
FUEL SYSTEM	46	2.7	2.4	0.0	0.0	2.7	2.5
OXYGEN SYSTEM	47	0.0	0.0	0.	0.	0.0	0.0
MISCELLANEOUS UTILITIES	49	0.0	0.0	0.	0.	0.0	0.0
INSTRUMENTS	51	1.7	1.6	1.8	1.6	3.5	3.1
AUTOPILOT	52	2.9	2.6	1.9	1.7	4.8	4.3
HF COMMUNICATIONS	61	0.1	0.1	0.7	0.6	0.8	0.7
UHF COMMUNICATIONS	63	0.2	0.2	0.4	0.3	0.6	0.5
INTERPHONE	64	0.	0.	0.	0.	0.	0.
IFF/SIF	65	0.	0.	0.	0.	0.	0.

F8111A CATEGORY II
MAINTENANCE MANHOURS PER FLYING HOUR BY WORK UNIT CODE
FOR NONSUPPORT GENERAL MAINTENANCE ACTIONS(PAGE 2 OF 3)

15 MAY 1970 THROUGH 15 NOVEMBER 1970

Table IV-1 (Concluded)

TITLE	WUC	LINE MMH/FH	LINE PERCENT OF TOTAL	SHOP MMH/FH	SHOP PERCENT OF TOTAL	TOTAL MMH/FH	TOTAL PERCENT OF TOTAL
MISC COMM EQUIPMENT	69	0.2	0.1	0.	0.	0.2	0.1
RADIO NAVIGATION	71	0.3	0.2	0.3	0.3	0.6	0.5
BOMBING NAVIGATION	73	8.2	7.3	11.1	9.9	19.3	17.3
FIRE CONTROL	74	0.0	0.0	0.5	0.5	0.6	0.5
WEAPONS DELIVERY	75	4.2	3.8	0.0	0.0	4.3	3.8
ELECTRONIC COUNTERMEASUR	76	0.	0.	0.	0.	0.	0.
PERSONNEL EQUIPMENT	96	0.	0.	0.	0.	0.	0.
EXPLOSIVE DEVICES	97	0.2	0.2	0.	0.	0.2	0.2
TOTALS FOR NONSUPPORT GENERAL		51.4	46.0	20.3	18.2	71.7	64.2
F8111A AIRCRAFT TOTALS		78.4		33.3		111.8	

F8111A CATEGORY II
MAINTENANCE MANHOURS PER FLYING HOUR BY WORK UNIT CODE
FOR NONSUPPORT GENERAL MAINTENANCE ACTIONS (PAGE 3 OF 3)

15 MAY 1970 THROUGH 15 NOVEMBER 1970

Table IV-2

COMPARISON OF ALLOCATED AND MEASURED MMH/FH
FOR SUPPORT GENERAL MAINTENANCE ACTION

Maintenance Task	WUC	Allocated MMH/FH	Measured MMH/FH	Comment
Ground handling service and flying	01	2.8	7.7	Low utilization rate resulting from low reliability caused increased ground handling.
Aircraft cleaning	02	0.2	0.3	Very little cleaning was required because of low utilization rate.
Hook phase of scheduled inspection	03	2.2	16.6	Large difference resulted from unrealistic contractor prediction and low utilization rate.
Special inspections	04	0.2	8.3	Large difference resulted from unrealistic contractor prediction, low utilization rate and several acceptance inspections during reporting period.
Acft and engine storage	05	0.0+	0.0	No storage actions.
Ground safety	06	0.2	0.1	About equal to predictions.
Preparation of aircraft records	07	0.1	0.3	About equal to predictions.
Special weapons handling	08	0.9	0.0	No special weapons work reported.
Shop support general	09	---	6.7	No prediction by contractor.

Table IV-3

COMPARISON OF ALLOCATED AND MEASURED MMH/FH FOR CORRECTIVE MAINTENANCE ACTIONS

Subsystem	WUC	Allocated MMH/FH	Measured MMH/FH	Comment
Airframe	11	2.5	6.0	The large difference is due to the low reliability of this subsystem.
Landing	13	0.2	4.0	TCTO accomplishment accounted for the majority of the difference.
Flight controls	14	1.3	10.4	Low reliability and catastrophic failures caused this large difference.
Escape capsule	16	0.2	3.5	Replacement of time change items accounted for large manhour expenditure.
Turbojet power plant	23	4.1	3.7	About equal to allocated.
Air conditioning and pressurization	41	0.5	4.7	TCTO accomplishment and repair of cracked duct in weapons bay caused large manhour expenditure.
Electrical power supply	42	0.3	0.2	About equal to allocated.
Lighting system	44	0.1	0.1	Equal to allocated.
Hydraulic and pneumatic power supply	45	0.5	0.2	About equal to allocated.
Fuel	46	0.4	2.7	System troubleshooting and fuel leaks accounted for differences.
Oxygen system	47	0.1	0.0	About equal to allocated.
Miscellaneous utilities	49	0.2	0.0	About equal to allocated.
Instruments	51	0.9	3.5	Troubleshooting resulting from low reliability consumed many manhours.

Table IV-3 (Concluded)

Subsystem	WUC	Allocated MMH/FH	Measured MMH/FH	Comment
Autopilot	52	0.7	4.8	Large difference due to low reliability.
HF communications	61	0.2	0.8	About equal to allocated.
UHF communications	63	0.4	0.6	About equal to allocated.
Interphone	64	0.1	0.0	About equal to allocated.
IFF	65	0.2	0.0	About equal to allocated.
Radio navigation	71	0.3	0.6	About equal to allocated.
Bombing navigation	73	2.5	19.3	Large difference due to low reliability.
Fire control	74	0.1	0.6	About equal to allocated.
Weapons delivery	75	0.3	4.3	Low reliability and TCTO accomplishment accounted for large difference.
Electronic countermeasures	76	1.1	0.0	Subsystem not utilized.
Personnel equipment	96	0.0+	0.0	Equal to allocated.

V. CONCLUSIONS

The aircraft demonstrated low reliability, with the airframe, flight controls, and bombing navigation subsystems having the lowest reliability.

The inertial reference unit, converter set, and the general purpose computer are identified as three specific components having unsatisfactory reliability when compared with apportioned values.

The difference between the allocated and attained values of MMH/FH for support general maintenance was attributed primarily to low flying hours while the large value of MMH/FH for corrective maintenance was caused by low aircraft reliability. The limited amount of flying time was due to the time required for technical order compliance, coldproof testing and temporary groundings along with low reliability (which reduced availability).

APPENDIX I - DATA SYSTEM

The Systems Effectiveness Data System (SEDS) was used for the collection, storage, retrieval, and analysis of the data for this evaluation. SEDS uses two sources of data for its inputs. A description of these two sources and a brief description of SEDS follows.

AFSC Form 258/258-4 Maintenance Data:

Data Collection Form.

The first source used for data input to SEDS was the Maintenance Discrepancy/Production Credit Record, AFSC Form 258/258-4 (figure I-A). This form is essentially hardware oriented.

Data Collection Procedures.

The AFSC Form 258/258-4 was filled out according to AFSC Maintenance Technical Directive 69-1 (reference 5). It was completed by the maintenance technicians to document every maintenance action on the aircraft. The single copy AFSC 258 was used to document such actions as fix-in-place repairs and support general maintenance. The four copy AFSC 258-4 was used to document removal of repairable parts which undergo further processing. The completion and initial editing of the 258 Forms was the responsibility of the F-111 Joint Test Force (JTF) maintenance organization. After the forms were completed they were key punched, edited, and used to update the SEDS maintenance history file regularly.

AFFTC Form 0-294 Mission Debriefing Data:

Data Collection Form.

The second source used for data input to SEDS was the Aircraft Debriefing Record, AFFTC Form 0-294 (figure I-B). This form is oriented toward subsystem mission performance.

Data Collection Procedures.

The AFFTC Form 0-294 was used to record the flight crew's analysis of a mission and to report system malfunctions which occurred during a mission. Information on the form included mission parameters such as aircraft serial number, mission number, date of mission, duration of flight, mission effectiveness, and codes which reflected the reliability of subsystems used during a mission. Codes used to record subsystem reliability were:

Code	Meaning
No Entry	Subsystem not used.
1	Subsystem operated satisfactorily.
2	Subsystem had a malfunction, but could be operated in a degraded state.
3	Subsystem failed, was inoperable or unusable, but did not cause a mission abort.
4	Subsystem failed and caused a mission abort.
5	Subsystem was flown with a known discrepancy.

If more than one malfunction was noted on a single subsystem, the reliability code of the most serious malfunction was used. The form was also used to record a brief narrative of the individual discrepancies and sufficient information to correlate the malfunction with the AFSC Forms 258/258-4 which were used to document troubleshooting and repair.

Accurate completion of the form was the responsibility of the flight crew and the reliability engineer. The forms were reviewed by the reliability engineer and then key punched into card form to update the debriefing file of the SEDS data base.

SEDS Data Base:

The SEDS data base was structured in the following manner. Each AFSC Form 258 maintenance report constituted a line item record in the maintenance part of the data base. Similarly, each AFFTC Form 0-294 mission debriefing report constituted a line item record in the operational part of the data base. Even though all maintenance actions were documented on the AFSC Forms 258, this did not mean that all maintenance to repair a particular malfunction was recorded on a single form. In some cases, more than one form was necessary to document all maintenance actions to clear a malfunction. A maintenance event was defined as all related maintenance actions required to clear a discrepancy. A SEDS computer program tied all related AFSC Forms 258/258-4 into a maintenance event. In addition, this program located the key work unit code (WUC) of the maintenance event, totaled the maintenance hours, and identified the action taken to fix the malfunction.

The data collected from the AFSC Forms 258/258-4 and AFFTC Forms 0-294 constituted the SEDS data base from which all data products contained in this report were derived. The basic philosophy of SEDS was to portray as realistically as possible the exhibited reliability and maintainability of the FB-111A. The effects of maintenance management, supply, and research and development functions were eliminated whenever possible.

Form Approved
Budget Bureau No. 21–R251

10	A JOB CONTROL NUMBER	B PRI	C TIME SPEC REQD	D WORK AREA	E ESTIMATED MANHOURS	F	1 COPY NR 0	2 REPORT NUMBER № 072201
	3 BASIC WORK CENTER		4 ITEM IDENTIFICATION		5 SERIAL NUMBER	6 TIME CYCLES MILES	7 WHEN D SCOVERED TIME *(Day-Mo-Yr-Hours)*	
	8 DATE TH S REPORT *(Day-Mo-Yr)*		9 WORK ORDER NUMBER		10 ORIG REPORT NUMBER	11 WHEN D SC CODE	12 ENG POSN NO	13 ACTIVITY IDENT
20	FAILED ITEM							
	14 MANUFACTURER		15 NOUN ENGINE TYPE MODEL SERIES MOD		16 SERIAL NUMBER	17 TIME CYCLES MILES	18 PART NUMBER	
	19 WORK UNIT CODE		20 SYMBOL	21 HOW MAL	22 FEDERAL SUPPLY CLASS	23	24	
30	INSTALLED ITEM							
	25 MANUFACTURER		26 NOUN - ENGINE TYPE MOLEL SERIES MOD		27 SERIAL NUMBER	28 TIME CYCLES MILES	29 PART NUMBER	
40 THRU 49	G SUPPLY DOCUMENT NUMBER *(Issue or Demand)*				30 DESCRIPTION OF DISCREPANCY OR MAINTENANCE REQUIRED			
							H DISCOVERED BY	

	31 PRI FIX	AFSC	SUF	NR	32 START	33 STOP	34 DELAY CODE	35 START	36 STOP	37 DELAY CODE	38 WORK UNIT CODE	39 ASSISTING WORK CENTER	40 UNITS	41 ACT
50														
51														
52														
53														
54														
55														
56														
57														
58														
59														

60	42 T O NUMBER	43 T O DATE *(Day Mo-Yr)*	44 T O PROCEDURE	45 TOOLS AGE	I CORRECTED BY
61 THRU 69	46 CORRECTIVE ACTION				J INSPECTED BY

K SUPERVISOR	L RECORDS ACTIONS UNCLEAR DISCREPANCY REPLACEMENT TIME CHANGE DATA TRANSCRIBED TO RECORDS	M DATE TRANSCRIBED *(Day Mo Yr)*	N TRANSCRIBED BY

AFSC FORM JAN 66 258 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE **MAINTENANCE DISCREPANCY/PRODUCTION CREDIT RECORD**

Figure 1–A (Front Side)

47. PIECE PARTS REPLACED DURING REPAIR

	PART NUMBER	NOUN	WORK UNIT CODE	CIRCUIT SYMBOL	TYPE FAILURE		QTY	HOW MAL	MANUFACTURER	FSC
					PRI	SEC				
70										
T										
H										
R										
U										
79										

CODING TO BE IN BLOCKS AS INDICATED

BLOCK 34 AND 37 DELAY CODES

- S AWAITING SUPPLIES AND/OR PARTS
- C DELAY DUE TO CONFLICTING MAINTENANCE
- A WORK STOPPAGE – NON-POWERED AGE OR RPIE
- E WORK STOPPAGE – POWERED AGE OR RPIE
- F FLYING
- P AWAITING PERSONNEL ASSISTANCE
- R ENGINE RUN-UP
- T AWAITING TRANSPORTATION
- X DELAY FOR WEATHER
- K DELAY FOR SPECIAL TEST EQUIPMENT
- M PREPLANNED MAINTENANCE DELAY

BLOCK 41 ACTION CODES

1. SERVICING
2. UNSCHEDULED MAINTENANCE
3. PREFLIGHT INSPECTION
4. POSTFLIGHT INSPECTION
5. HOURLY POSTFLIGHT
6. PERIODIC INSPECTION
7. SPECIAL INSPECTION
8. INDEPENDENT
9. RESEARCH AND DEVELOPMENT

BLOCK 44 T O. PROCEDURE CODES

1. ADEQUATE
2. INADEQUATE
3. INCOMPLETE
4. MISIDENTIFIED
5. NOT AVAILABLE
6. INCORRECT INFORMATION
7. OTHER

BLOCK 45 TOOLS/AGE CODES

1. TOOLS ADEQUATE
2. TOOLS INADEQUATE
3. TOOLS NOT AVAILABLE
4. TEST EQUIPMENT ADEQUATE
5. TEST EQUIPMENT INADEQUATE
6. TEST EQUIPMENT NOT AVAILABLE
7. TOOLS AND TEST EQUIPMENT ADEQUATE
8. TOOLS AND TEST EQUIPMENT INADEQUATE
9. TOOLS AND TEST EQUIPMENT NOT AVAILABLE

* GPO 1988 O—700-881

AFSC (AAFB)

Figure I–A (Back Side)

AIRCRAFT DEBRIEFING RECORD

TYPE (FB-111A)

CARD NO	1 AIRCRAFT TYPE	2 ID SERIAL NO	3 MISSION NO	4 DATE DAY MONTH YEAR	5 T O TIME HOUR MIN	6 DURATION HOUR MIN	7 TYPE MISSION	8 EFFECT	9 REMARKS
1	F B 1 1 1 A	A							

10 HIGH MACH	11 HIGH ALT	12 AIR REFUEL (RCVD LBS TRANS)	13 AIR RE-FUEL CONTACTS	14 SUPER TIME HR MIN	15 WIRE SWEEPS	16 O & M BLOCK 1000 HOUR MIN	17

18 PILOT	19 NAVIGATOR	20

CARD NO.	BLOCK NO	REL CODE	SYSTEM NAME	CARD NO	BLOCK NO	REL CODE	SYSTEM NAME
	21		AIRFRAME		51		INERTIAL NAVIGATION
	22				52		ATTACK RADAR
	23		LANDING GEAR		53		RADAR ALTIMETER
	24		FLIGHT CONTROL		54		TFR
	25		ESCAPE CAPSULE		55		DOPPLER
	26		TURBO-JET ENGINE		56		ASTRO-TRACKER
	27		AIR CONDITIONING & PRESSURIZATION		57		DISPLAY SUBSYSTEM
	28		ELECTRICAL POWER		58		ODS
	29		LIGHTING SYSTEM		59		DUAL INDICATING BOMB TIMER
	30		HYDRAULIC & PNEUMATIC POWER		60		COMPUTER COMPLEX
	31		FUEL		61		
	32		AIR REFUELING		62		
	33				63		PYLONS
	34		OXYGEN SYSTEM		64		WEAPONS BAY
2	35		MISCELLANEOUS UTILITIES	2	65		WEAPONS CONTROL
	36		INSTRUMENTS		66		WEAPONS RACKS
	37				67		
	38		AUTO PILOT		68		TRACK BREAKER SYSTEM
	39		AIR DATA		69		CMRS
	40		HF COMMUNICATIONS		70		CMDS
	41		UHF COMMUNICATIONS		71		RHAWS
	42		INTERPHONE		72		
	43		IFF/SIF		73		
	44		MISCELLANEOUS COMMUNICATION EQUIPMENT		74		INSTRUMENTATION
	45		TACAN		75		
	46		ILAS		76		
	47		UHF/ADF		77		
	48		RNDZ BEACON		78		
	49				79		
	50				80		

MISSION OBJECTIVES	% SUCCESS

SIGNATURE OF AIRCRAFT COMMANDER	SIGNATURE OF DEBRIEFER

CODE FOR BLOCKS AS INDICATED

BLOCK 7 (TYPE MISSION)	BLOCK 8 (MISSION EFFECTIVENESS)	RELIABILITY CODES
01 TRANSITION OR TRAINING	1 FLOWN AS BRIEFED	BLANK EQUIPMENT NOT USED
02 TEST SUPPORT	2 MISSION DEVIATION	1 OPERATED SATISFACTORILY
03 OTHER SUPPORT	3 AIR ABORT	2 DEGRADED OPERATION
04 SYSTEMS TEST	4 GROUND ABORT	3 FAILED BUT NO ABORT
05 PERFORMANCE TEST	5 FLOWN AS BRIEFED & ADDITIONAL EVALUATION PERFORMED	4 FAILED AND ABORT
06 STABILITY AND CONTROL TEST	NOTE, MISSIONS CHANGED FOR OTHER THAN MAINTENANCE ARE CODED 1	5 FLOWN WITH KNOWN DISCREPANCY

AFFTC FORM OCT 68 0-294

PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE

Figure I-B (Front Side)

DISCREPANCIES [1]												
CARD 3	BLOCK	REL CODE	JOB CONTROL NUMBER	WHEN DISC	WORK UNIT CODE	HOW MAL	ACTION	POSITION	BITE	SAFETY CODE	TIME TO FAIL HRS MIN	
DESCRIPTION OF DISCREPANCY												
CARD 3	BLOCK	REL CODE	JOB CONTROL NUMBER	WHEN DISC	WORK UNIT CODE	HOW MAL	ACTION	POSITION	BITE	SAFETY CODE	TIME TO FAIL HRS MIN	
DESCRIPTION OF DISCREPANCY												
CARD 3	BLOCK	REL CODE	JOB CONTROL NUMBER	WHEN DISC	WORK UNIT CODE	HOW MAL	ACTION	POSITION	BITE	SAFETY CODE	TIME TO FAIL HRS MIN	
DESCRIPTION OF DISCREPANCY												
CARD 3	BLOCK	REL CODE	JOB CONTROL NUMBER	WHEN DISC	WORK UNIT CODE	HOW MAL	ACTION	POSITION	BITE	SAFETY CODE	TIME TO FAIL HRS MIN	
DESCRIPTION OF DISCREPANCY												
CARD 3	BLOCK	REL CODE	JOB CONTROL NUMBER	WHEN DISC	WORK UNIT CODE	HOW MAL	ACTION	POSITION	BITE	SAFETY CODE	TIME TO FAIL HRS MIN	
DESCRIPTION OF DISCREPANCY												
CARD 3	BLOCK	REL CODE	JOB CONTROL NUMBER	WHEN DISC	WORK UNIT CODE	HOW MAL	ACTION	POSITION	BITE	SAFETY CODE	TIME TO FAIL HRS MIN	
DESCRIPTION OF DISCREPANCY												
CARD 3	BLOCK	REL CODE	JOB CONTROL NUMBER	WHEN DISC	WORK UNIT CODE	HOW MAL	ACTION	POSITION	BITE	SAFETY CODE	TIME TO FAIL HRS MIN	
DESCRIPTION OF DISCREPANCY												
CARD 3	BLOCK	REL CODE	JOB CONTROL NUMBER	WHEN DISC	WORK UNIT CODE	HOW MAL	ACTION	POSITION	BITE	SAFETY CODE	TIME TO FAIL HRS MIN	
DESCRIPTION OF DISCREPANCY												

[1] *NOTE*

a Obtain Block Number from front of this form

b Obtain Job Control Number, When Discovered Code, Work Unit Code, How Malfunctioned Code, and Action Taken Code from AFSC Form 258/AFTO Form 349 as applicable, which shows the primary cause of failure

Figure I–B (Back Side)

APPENDIX II

CALCULATION OF SUBSYSTEM MISSION RELIABILITY

The following statistics were calculated for each subsystem:

1. Mean time between discrepancies (MTBD)
2. Mean time between failures (MTBF)
3. Mean time between aborts (MTBA)

These values were computed as follows:

$$MTBD = \frac{T}{N_d + N_f + N_a}$$

$$MTBF = \frac{T}{N_f + N_a}$$

$$MTBA = \frac{T}{N_a}$$

Where:

T = total system operating (flying) time.

N_d = number of missions on which degraded operation was recorded against the subsystem.

N_f = number of missions on which a no-abort failure was recorded against the subsystem.

N_a = number of missions on which an abort was recorded against the subsystem.

In addition, the statistically derived 90-percent lower confidence limits (LCL's) for the means were calculated. A 90-percent lower confidence limit for a given parameter is that value which the true value would equal or exceed for a given sample size with 90-percent probability. In other words, based on the accumulated data, we can be 90 percent sure that the MTBF is greater than the lower 90-percent confidence limit.

The method used to determine the LCL employed the chi-square (χ^2) distribution using fixed truncation time for the tests:

$$\text{Lower Limit} = \frac{2T}{\chi^2_{(\alpha,\ 2R+2)}}$$

Where

T = total system operating time

R = number of failures accumulated

α = acceptable risk of error (10 percent) or

$1-\alpha$ = confidence level (90 percent)

χ^2 = the critical value for the chi-square distribution with risk, α, and the degrees of freedom, $2R + 2$.

The Subsystem Mission Reliability Report also contains the following statistics computed to show the probability that a subsystem will be usable on any mission regardless of duration:

1. Probability of no discrepancies (P_{nd})
2. Probability of no failures (P_{nf})
3. Probability of no aborts (P_{na})

These probabilities were calculated as follows:

$$P_{nd} = \frac{N_s}{N_s + N_d + N_f + N_a}$$

$$P_{nf} = \frac{N_s + N_d}{N_s + N_d + N_f + N_a}$$

$$P_{na} = \frac{N_s + N_d + N_f}{N_s + N_d + N_f + N_a}$$

The 90-percent LCL's associated with these probabilities are also included. The following binomial distribution equation was used to compute the LCL's.

$$\sum_{i=N_s}^{N} \binom{N}{i} (p)^i \quad (1-p)^{n-i} = \alpha$$

Where

N = sample size

N_s = number of successful missions

p = lower confidence limit probability

α = acceptable risk level (10 percent)

An iterative method was used to solve the equation for the LCL. Any large differences between some of the measured mean times and probabilities and the associated LCL's resulted from the low utilization rates of some subsystems.

The following formula was used to calculate overall aircraft mean time between subsystem failures:

$$\text{Mean Time Between Subsystem Failures} = \frac{\text{Total flying time}}{\sum_{\text{all subsystems}} N_f + \sum_{\text{all subsystems}} N_a}$$

APPENDIX III - HARDWARE FAILURES

A subsystem hardware failure was initially defined as any discrepancy which was corrected by maintenance "action taken" codes F, G, K, L, P, R, S, or Z and which did not have one of the following "how malfunctioned" codes: 086, 092, 105, 106, 108, 158, 230, 204, 246, 301, 303, 709, 878, 447, 518, 602, 731, 793, 797, 798, 799, 800, 801, 802, 803, 804, 812, 877, 911, 931, 948, 796, 553, 142, or 424 (table III-A defines these codes).

In addition to the above algorithm which was used as a preliminary screen for failures, a manual editing technique was employed to cross check data accuracy and to further select failures. During the manual editing phase, the following types of maintenance actions were not considered failures:

1. Components which were removed from the aircraft, but tested good at the field maintenance level.
2. Secondary failures (those caused by the failure of a different component).
3. Correction of maintenance errors.
4. Minor maintenance actions such as replacement of missing screws, installation of safety wire, etc.

For the calculation of observed MTBF, the following formula was used:

$$\text{MTBF} = \frac{\text{Flying hours}}{\text{Observed failures}}$$

Table III-A

CODE DEFINITIONS

ACTION TAKEN CODES

Code	Definition
F	Repair
G	Repair and/or replacement of minor parts, hardware and softgoods
K	Calibrated-adjustment required
L	Adjust or reset
P	Removed
R	Remove and replace
S	Remove and reinstall
Z	Corrosion treatment

HOW MALFUNCTIONED CODES

Code	Definition
086	Improper handling
092	Mismatched
105	Loose or damaged bolts, nuts, screws, rivets, fasteners, clamps, and common hardware
106	Missing bolts, nuts, screws, rivets, fasteners, clamps, or other common hardware
108	Broken, faulty, or missing safety wire or key
158	Launch damage
230	Dirty, contaminated, or saturated by foreign material
204	Accidental explosion of, or damage from on-board munitions
246	Improper or faulty maintenance
301	Foreign object damage
303	Bird strike damage
709	Administrative condemnation
878	Weather damage
447	Wrong logic
518	Improper routing
602	Failed or damaged due to malfunction of associated equipment or item

Table III-A (Concluded)

Code	Definition
731	Battle damage
793	No defect - TCTO kit received
797	No defect - technical order previously complied with
798	No defect - technical order not applicable, equipment to be replaced, modified or not installed
799	No defect
800	No defect - component removed and/or re-installed to facilitate other maintenance
801	No defect - technical order compliance
802	No defect - partial technical order compliance
803	No defect - removed for time change
804	No defect - removed for scheduled maintenance
812	No defect - indicated defect caused by associated equipment malfunction
877	Transportation damage
911	Engine TCTO correction code
931	Accidental or inadvertent operation, release or activation
948	Operator error
796	No defect - removed for reliability assessment
553	Does not meet specification
142	Engine removed, excessive maintenance
424	External power source

APPENDIX IV

CALCULATION OF MAINTENANCE MANHOURS PER FLYING HOUR

WUC's were used in maintenance data recording to identify the specific hardware item that was being worked on or to identify the type of maintenance. These are five-digit, alphanumeric codes specified in the Work Unit Code Manual, T.O. 1F-111(B)(Y)A-06 (reference 6). The first two digits of a WUC (called a WUC group) identify an aircraft system. For example, 71 identifies the radio navigation system. The third digit usually identifies a subsystem. For example, 71A identifies the tacan subsystem. The fourth and fifth digit usually identify assemblies and components. For example, 71AA0 identifies the tacan receiver/transmitter. Maintenance accomplished and documented against aircraft systems is called corrective maintenance. WUC's beginning with 01 through 09 identify support general maintenance actions such as aircraft cleaning, servicing, and look phases of inspections.

The MMH/FH expended against each aircraft system and for each type of support general maintenance was calculated. These statistics were calculated by retrieving maintenance data from the 258 Data System by the first two digits of the WUC (WUC group) and dividing the sum of maintenance manhours for each WUC group by the total flying time for the reporting period. Support general maintenance was denoted by WUC groups 01 through 09. Corrective maintenance was denoted by WUC groups 11 through 97. Maintenance was additionally identified as being performed at the line (organizational) level or the shop (field) level.

APPENDIX V

FB-111A FAILURE TABULATION BY WUC

15 May 1970 - 15 Nov 70

WUC	Part No.	Part Name	Quantity	Failure Symptoms or Description
		1100 - AIRFRAME		
11ABE	A-308-8	Support Assy, Fwd Equipment Bay Door	1	Electronic bay door broken.
11ABK	A-308-18	Strut Assy	1	Strut assembly for panel No. 1116 broken.
11AC9	12H1552-17	Pneumatic Line	1	Left overwing fairing pneumatic line broken.
11AD9	20791-102-6	Solenoid	1	Entry step solenoid pin broken.
11AGF	12B10962-3	Cover, Fwd Engine Access	1	Left engine fire door hinges worn.
11AJE	12T050-837	Vertical Stabilizer Tip	1	Vertical tail tip plastic damage repaired locally.
11B00	324132	Seal	1	Right wing flap seal missing.
11B00	384132	Seal	1	Seal forward of right wing seal damaged.
11BAH	12W5153-804	Wing, Tip	1	Wing tip cracked. Repaired locally.
11BAK	12W7925-837	Trailing Edge	1	Panel 5429 cracked. Repaired locally.
11BAK	12W7905	Trailing Edge	1	Panel 6429 cracked. Repaired locally.
11BAK	12W9343-8	Trailing Edge	1	Seal on rib of left wing trailing edge torn.
11BAL	12W7600-33	Covers, Access	1	Panel No. 5436 damaged. Repaired locally.
		1300 - LANDING GEAR		
13DAA	12L140-819	Door, Aft	1	Main landing gear aft fairing door delaminated. Repaired locally.
13GAH	09251016	Tire, Main	1	Tire worn beyond limits.
13GAH	6501971	Tire, Main	1	Tire worn beyond limits.
13GAH	9163415	Tire, Main	1	Tire worn beyond limits.
13GBG	0228734	Tire, Nose	4	Tire worn beyond limits.
13LAT	12B13339-1	Panel, Tail Hook	3	Tail hook panel lost in flight.
		1400 - FLIGHT CONTROLS		
14BC9	959773C0345180	Hose, Spoiler	1	Spoiler hoses buckled at wing pivot area.
14BC9	959782C0345	Hose, Spoiler	1	Spoiler hoses buckled at wing pivot area.
14BC9	9597730345C135	Hose, Spoiler	1	Spoiler hoses buckled at wing pivot area.
14CBC	475J650	Joint, Swivel Expansion	1	Right stabilizer actuator swivel joint leaking.
14CCC	12W9885-13	Seal, Horizontal Stabilizer to Fuselage	1	Seal deteriorated.
14D00	12W9921-26	Rib Assy	1	Rib assy warped.
14DAB	544094-2-1	Gear Box, Angle	1	Worn beyond limits.
14DAE	541818-2-1	Actuators, Linear	1	Left flap outboard actuator broke (damaged many other parts).
14DAG	12M2628-1	Gear Assy, Airflow Deflector Door	1	Left wing No. 5 air deflector connector broken.
14DCY	12M9805-7	Door, No. 5 Airflow Deflector	1	Worn hinges.
14DC9	12M3344-12	Seal, Flap	1	Flap seal torn.
14DCM	12W9910-807	Vane, No. 4	1	Vane buckled.
14DCX	12W9970-6	Vane, No. 5	1	Vane dented.
14HAJ	42304C2C3A3	Indicator, Flap/Slat/Wing Position	1	Indicator did not follow wing position.
14DC	12W8210	Flap, No. 5	1	Right inboard flap punctured. Fiberglass patch applied.

APPENDIX V (Continued)

WUC	Part No.	Part Name	Quantity	Failure Symptoms or Description
		1600 - ESCAPE CAPSULE		
16ABB	12K3250-813	Counterpoise	2	Counterpoise inoperative.
16CA9	12K021-11	Tube	1	Emergency oxygen supply tube cracked and leaking.
		2300 - TURBOJET ENGINE		
23MAF	537230	Breather-Pressurizing Valve	1	Excessive smoke on engine shutdown was corrected by replacement of valve.
23VCA	871AV1	Ice Detector	1	Icing caution lamp on throughout flight. Corrected by replacement of ice detector.
23VGA	47209-002-04	Valve, Air Pressure Regulating	1	Valve had internal failure.
23VGG	47209-001-03	Valve, Nacelle Vent Ejector	1	Valve had internal failure.
23VGH	12P4970-1	Tube Assy	1	Broken.
23VGH	12P4972-5	Manifold, Ejector Nacelle Vent	1	Manifold broken.
23VJG	2398314	Valve, Emergency Shuttle	1	Seal on shuttle valve return leaking.
23VJG	717699L3	Valve, Emergency Shuttle	1	Shuttle valve leaking.
23YDA	8588-12B	Indicator, Turbine Inlet Temperature	1	Indicator failed self test.
		41000 - AIR CONDITIONING AND PRESSURIZATION		
41000	12Y919-1	Duct	1	Duct cracked.
41AAB	26640417	Valve, Shutoff Aero Screen	1	Vortex destroyer air inoperative. Corrected by valve replacement.
41ABA	12Y838-47	Duct	1	Duct cracked.
41BAB	711020-1	Valve, Control Regulating Cabin Pressure	1	Valve inoperative.
		42000 - ELECTRICAL POWER		
42AFA	10786-5	Monitor, External Power	2	Power monitor inoperative.
		46000 - FUEL		
46AAG	8120	Intermediate Device	1	Fuel totalizer did not decrease when fuel was off-loaded. Corrected by replacement of intermediate device.
46ABB	8TJ6ZGBC3	Transmitter, Flow Rate TRU63/A	1	Faulty transmitter caused system not to indicate fuel flow.
46BAG	21SN04-4B	Switch, Manifold Low Pressure	1	Manifold fuel warning erroneously on. Corrected by switch replacement.
46CCO	C2005-1	Relay	1	Failure of aerial refueling receptacle to retract required relay replacement.
46HAH	NSL	Left Saddle Tank	1	Saddle tank leaking. Repaired locally.
		49000 - MISCELLANEOUS UTILITIES		
49AAA	843650A	Element Cable	1	Element cable broken.
49AAA	728068	Elemen Cable	1	Inoperative.
		51000 - INSTRUMENTS		
51AAY	18007-7A10A1	Indicator, Vertical Speed/ Altitude	2	Intermittent OFF flag.
51AAZ	7200	Transmitter, Accelerometer	1	Transmitter inoperative.
51BAF	103777	Computer, Flight Director	1	Incorrect pitch steering bar operation necessitated alignment of flight director computer.

APPENDIX V (Continued)

WUC	Part No.	Part Name	Quantity	Failure Symptoms or Description
51GAA	8KE65AG2	Controller, Compass System	1	Intermittent auxiliary attitude lamp corrected by controller replacement.
51DAA	CLABU11A	Clock, Aircraft, Mechanical	2	Clock intermittent.
		52000 - AUTOPILOT		
52AAF	756D512G1	Gyro, Rate	1	Continuous roll channel light corrected by replacement of gyro.
52ABA	273E750G1	Computer, Flight Control Pitch	1	Intermittent pitch channel warning lights required replacement of a power supply cube.
52ACA	273E770G1	Computer, Flight Control Yaw	1	Mach hold deviations required replacement of A2 board.
52ACA	273E770G1	Computer, Flight Control Yaw	1	Replacement of A3 board was required when the autopilot would not engage.
52ACA	273E770G1	Computer, Flight Control	1	Inability to engage attitude stability mode required cleaning and reseating of A3 board.
		63000 - UHF COMMUNICATIONS		
63AAO	522-4304-001	Receiver-Transmitter	2	Realignment required to lower guard receiver audio level in one case and make system transmit in the other case.
63ACB	11D2100-3	Antenna, Upper	1	Peeling covering on upper UHF antenna was repaired locally.
		71000 - RADIO NAVIGATION		
71BAO	11D2100-3	Receiver-Transmitter RT-384	1	Tacan range error required replacement of R/T unit.
71COO	C147-1	Cable, Antenna	1	ILS was returned to operation by repair of antenna cable.
		73000 - BOMBING NAVIGATION		
73CAP	F51860001000	Indicator, Radar Altimeter	2	Inoperative indicator caused both LARA channels to fail.
73HAO	68144-301-31	Inertial Peference Unit	3	All INS failures were caused by the reference unit.
73HAO	58144-301-41	Inertial Reference Unit	1	All INS failures were caused by the reference unit.
73HGO	6861600	Computer, General Purpose	1	Both computers were returned to the contractor for repair.
73HJO	C704-722-C81	Converter		One converter was repaired by replacement of the power supply and the other was returned to depot.
73JAO	7335131G1	Antenna Assy	1	Azimuth motor A1B2 burned out.
73JEO	7335131G3	Indicator-Recorder	1	Intermittent sweep jitter corrected by replacement of indicator.
73JFO	763710G1	Control, Radar Set	1	Replacement of time delay relay K1 was required when radar would not come on.
73JHO	7335135G3	Synchronizer	1	Inoperative air mode of radar was corrected by replacement of synchronizer.
73JHO	7335135G3	Synchronizer	2	Intermittent azimuth mark operation and loss of sweep was corrected, respectively, by replacement of pins D and EE on plug P10053.
73JHO	7335135G3	Synchronizer	1	Apparent power supply overloading was corrected by replacement of power supply (PN7332002G3).
73KOO	NSL	Radar Set, Terrain Following	1	Loss of both radar channels required repair of interconnection wiring.

APPENDIX V (Concluded)

WUC	Part No.	Part Name	Quantity	Failure Symptoms or Description
73KFO	582358-2	Synchronizer-Transmitter	1	Intermittent failure corrected by replacement of modulator assy in synchronizer.
73LAO	G7123-001-01	Electronic Unit	1	Inoperative doppler above 10,000 feet altitude corrected by replacement of electronic unit.
73LAO	G7123-001-01	Electronic Unit	1	Inoperative doppler repaired by replacement of card A17 in electronic unit.
73MBO	668500-7	Electronic Unit	1	Inoperative astro-tracker repaired by replacement of electronics unit.
		75000 - WEAPONS BAY		
75BAB	12S901-807	Doors, Lower Weapons Bay	1	Damaged door required replacement.
75BAG	12M635-833	Door, Safety Pin Lock	1	Damaged door required replacement.
75BAK	175170-1	Actuator Assy Hydromechanical	1	Weapons bay door actuator inoperative.
75BAY	12S932-832	Panel	1	Rear upper panel on right weapons bay door torn.

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1. F-111 Avionics System Reliability Program Review, Autonetics Corporation, Anaheim, California, 5 November 1969.

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3. Maintainability Specification for Model FB-111A Weapon System, FZM-12-6140A, General Dynamics/Fort Worth, Texas, 30 November 1967.

4. Maintainability Engineering Analysis Data, FZM-12-6118-3, General Dynamics/Fort Worth, Texas, 31 March 1969.

5. Air Force Systems Command System Effectiveness Data System AFSC Form 258/258-4 Maintenance Data Recording Procedures, Maintenance Technical Directive 69-1, 15 September 1969.

6. Work Unit Code Manual, T.O. 1F-111(B)(Y)A-06, 7 June 1968.